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ABSTRACT

A theoretical analysis was performed to determine the landing dynamics on a hard flat surface and a hard irregular surface. The study shows that for low coefficients of friction, surface irregularity is significant in determining vehicle stability. However, the flat surface at large values of coefficient of friction appears to adequately represent the stability characteristics of the irregular surfaces studied in this memorandum.

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MEMORANDUM FOR FILE

Introduction

In Reference 1, studies were made of a LEM vehicle landing on hard surfaces of various coefficients of friction and soil surfaces. However, all the surfaces considered were flat. A downhill landing on a hard flat surface with a high coefficient of friction was considered to be the most unstable of the hard surface landings. In this memorandum, irregular hard surfaces with the same effective slope limitation as the flat surfaces were studied by means of the computer landing dynamics program developed by the Bendix Corporation. Details of the computer program are given in Reference 2. Thus, the combined effects of irregularity and coefficient of friction on landing stability were determined.

Analysis

The landing dynamics of a vehicle on two surface profiles sketched below were studied using the landing dynamics computer program developed at the Bendix Corporation.

sinusoidal   triangular
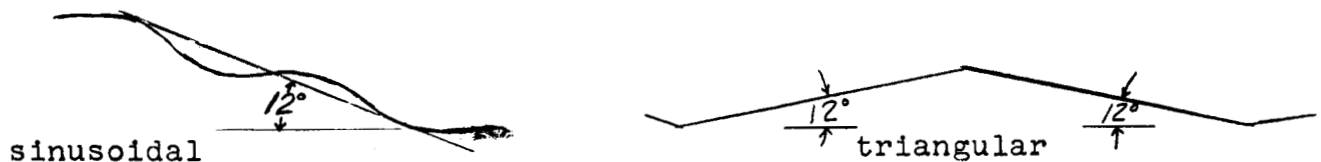
For the sinusoidally shaped surface, the variables included the amplitude, wavelength, and coefficient of friction of the surface. In the case of the triangular surface, the pitch, or distance between peaks, was varied. In both types of surfaces, the initial point of contact of the footpad with the surface was varied. The maximum effective slope of the surface was always equal to or less than 12° in order to correlate this analysis with the 12° sloped flat surface analysis.
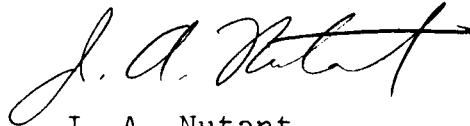
Figure 1 shows the stability profiles for a flat surface and a sinusoidal surface, both having a coefficient of friction equal to 0.5. The greater instability of the sinusoidal surface is quite noticeable. Figure 2 shows the stability profiles for the same surfaces as in Figure 1, but with a coefficient of friction equal to 1.0. The profiles for the two surfaces are seen to be almost coincidental.

In Figure 3, the stability profiles for a flat surface with a coefficient of friction equal to 10.0 and two irregular surfaces, each with a coefficient of friction equal to one, are plotted. The small differences among the three surfaces are thought to be within the accuracy of the analysis.

Conclusions

The preceding analysis shows that for hard surfaces with a low coefficient of friction, the irregularity of the surface is quite significant in the stability of the landing. However, this significance decreases with increasing coefficient of friction to the point where there is little difference between stability characteristics on a flat surface with essentially an infinite coefficient of friction and either of the irregular surface models considered in this memorandum.

J. A. Nutant

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REFERENCES

1. "Soil Effects of Lunar Landing Dynamics", J. A. Nutant, Memorandum For File, Bellcomm, Inc., September 3, 1965

2. "Final Report, Lunar Landing Dynamics, Specific Systems Engineering Studies", Report No. MM-65-4, Bendix Products Aerospace Division, June, 1965.
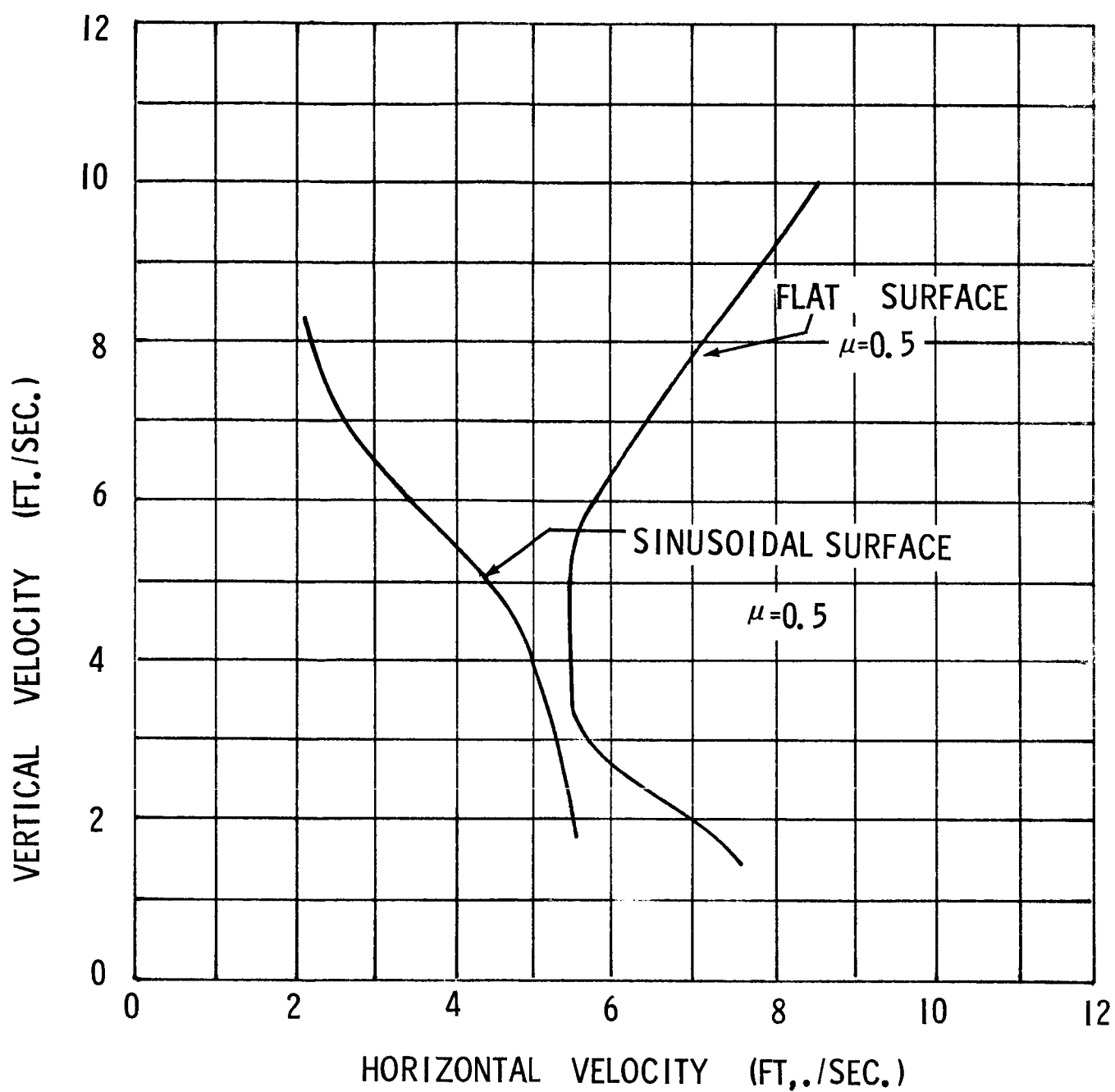
FIGURE I HARD SURFACE STABILITY PROFILES FOR μ =0.5
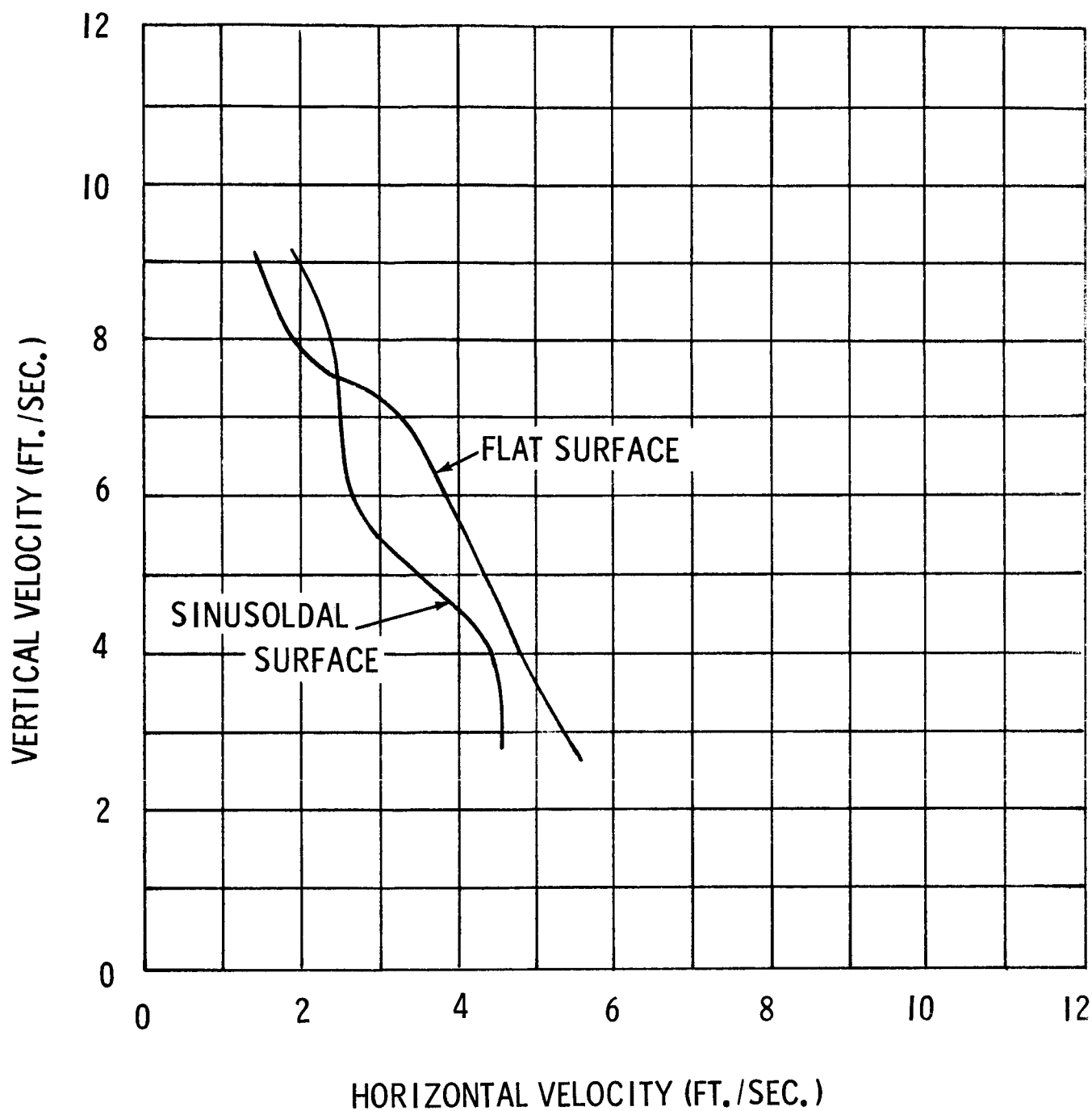(μ =COEFFICIENT OF FRICTION)

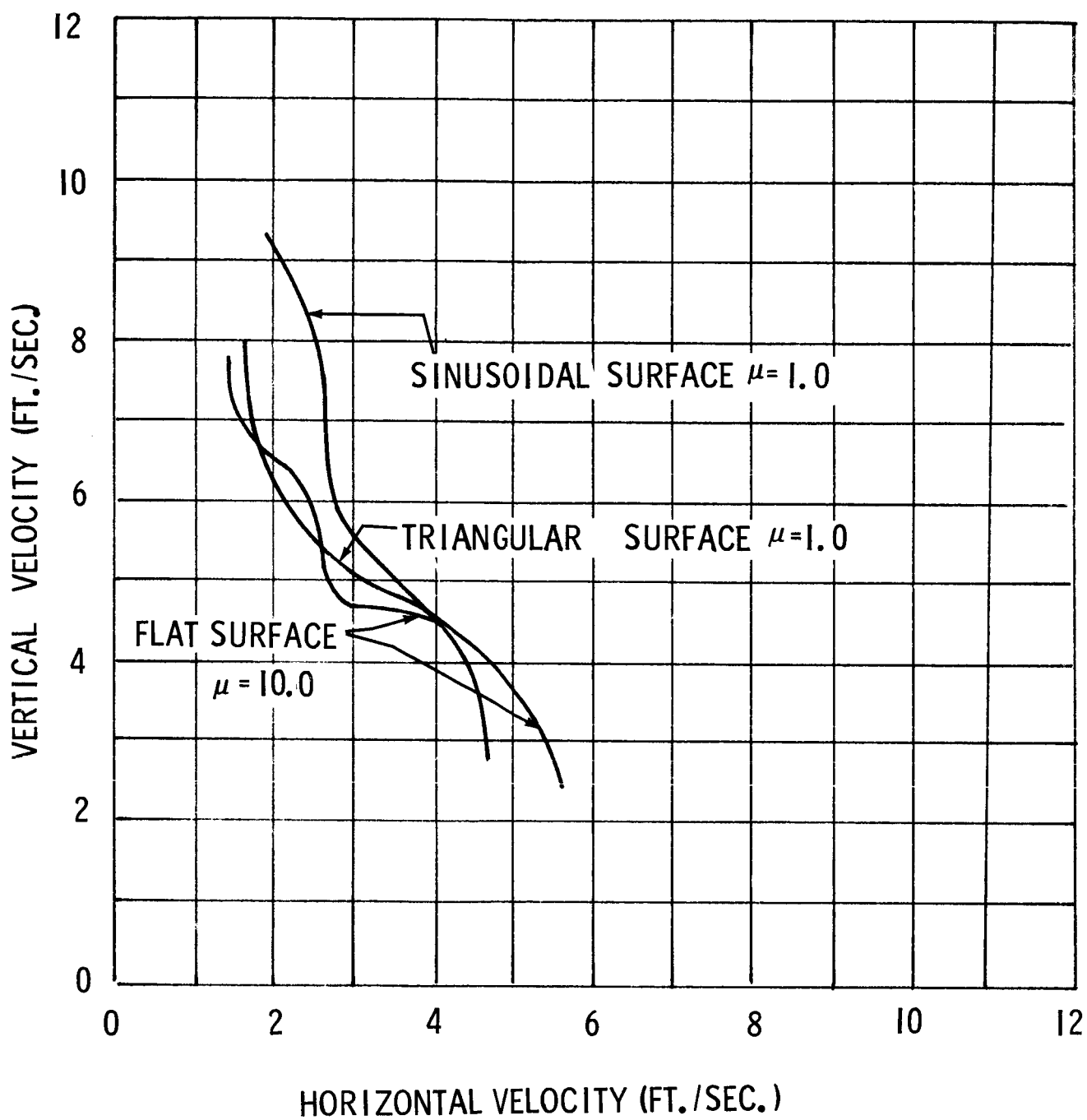FIGURE 2 HARD SURFACE STABILITY PROFILES FOR μ =1.0
(μ=COEFFICIENT OF FRICTION)

FIGURE 3   HARD SURFACE   STABILITY   PROFILES